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EXHAUST PURIFICATION DEVICE FOR INTERNAL COMBUSTION ENGINE
[Nainen kikan no haiki joka sochi]

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[Claims] /*

[Claim 1] An exhaust purification device for an internal combustion engine provided with a turbo supercharger having a turbine that is provided to an exhaust system of the internal combustion engine and a compressor that is provided to an intake system, a filter that is provided downstream of the turbine in the exhaust system and collects particulate matter inside exhaust gas, a catalyst that is provided upstream of the turbine in the exhaust system and has at least oxidizing functionality, a filter regeneration judging means for judging whether or not particulate matter accumulated on the filter has spontaneously ignited or whether or not the filter is undergoing forced regeneration, an operating state judging means for judging whether or not a specific operating state is in effect whereby a flow rate of exhaust gas flowing into the filter is low, and a controlling means for supplying a reducing agent to the catalyst when the filter regeneration judging means has judged that particulate matter is undergoing spontaneous ignition or that the filter is undergoing forced regeneration and the operating state judging means has judged that the specific operating state is in effect.

[Claim 2] The exhaust purification device for an internal combustion engine as claimed in Claim 1, wherein the turbo supercharger has a waste valve that causes the exhaust gas upstream

* Claim and paragraph numbers correspond to those in the foreign text.

of the turbine in the exhaust system to bypass down to downstream of the turbine or a boost pressure adjusting mechanism whereby boost pressure can be variably controlled, and the controlling means either closes the waste gate valve or controls the boost pressure adjusting mechanism such that the boost pressure rises when the reducing agent is applied to the catalyst.

[Claim 3] The exhaust purification device as claimed in Claim 1, wherein the controlling means supplies reducing agent to the catalyst when the filter regeneration judging means judges that particulate matter is spontaneously igniting or the filter is undergoing forced regeneration, and the operating state judging means judges that a specific operating state has continued for at least a predetermined amount of time.

[Claim 4] The exhaust purification device for an internal combustion engine as claimed in Claim 1, further comprising an accumulated amount estimating means for estimating an accumulated amount of particulate matter collected on the filter, the turbo supercharger having a waste valve that causes the exhaust gas upstream of the turbine in the exhaust system to bypass down to downstream of the turbine or a boost pressure adjusting mechanism whereby boost pressure can be variably controlled, and the controlling means supplying reducing agent to the catalyst and either opening the waste gate valve or controlling the boost pressure adjusting mechanism such that the boost pressure falls when an

accumulated amount of particulate matter estimated by the accumulated amount estimating means exceeds a predetermined value.

[Claim 5] The exhaust purification device for an internal combustion engine as claimed in Claim 1, wherein the specific operating state is an operating state in which an exhaust gas flow rate falls to within a specific range due to activation of an exhaust brake during ordinary operation or during motoring with fuel supply stopped, and the controlling means supplies reducing agent to the catalyst if in the specific operating state the filter regeneration judging means judges that particulate matter is spontaneously igniting or the filter is undergoing forced regeneration.

[Detailed Description of the Invention]

[0001] [Field of the Invention]

The present invention relates to an exhaust purification device for an internal combustion engine having a filter that collects particulate matter in exhaust gas that is emitted by a diesel engine or other type of internal combustion engine.

[0002] [Prior Art]

HC, CO, NOx, and other particulate matter is contained in exhaust gas that is emitted by a diesel engine, for example, and particulate filters have been proposed as post-processing devices for dealing with this particulate matter. Such filters employ a so-called wall-flow system whereby upstream and downstream openings in multiple passages along a direction of flow of exhaust gas are closed in an

alternating fashion, allowing exhaust gas to flow through porous dividing walls forming the passages.

[0003] Accordingly, harmful substances, such as black smoke in the exhaust gas that is emitted by the diesel engine, are appropriately collected by the filter. During acceleration or high-speed travel of the vehicle, harmful substances collected by the filter are re-combusted by the exhaust gas which is now hot. Furthermore, when a predetermined amount or more of the harmful substances has been collected on the filter, the filter is heated by an external heating means, and the collected harmful substances are re-combusted. By regenerating the filter when needed in this manner, harmful substances in the exhaust gas can be collected successfully.

[0004] [Problems to be Solved by the Invention]

Operating conditions are not constant in a diesel engine. For example, the amount of fresh air taken in drops due to a drop in rpm during low-rpm/low-load operation or during idling, and the flow rate of exhaust gas becomes extremely small because the amount of fuel being supplied falls. Therefore, during low-rpm/low-load operation or during idling, the heat produced by re-combustion of the harmful substances is insufficient to carry away the exhaust gas when a regeneration process is executed by heating the filter, leading to a rise in temperature of the filter and therefore possible deterioration or breakage. Furthermore, during low-rpm/low-load operation or during idling, the oxygen concentration of the exhaust

gas also rises, causing the harmful substances collected on the filter to become more readily combustible, which also can cause deterioration or breakage as the filter heats up.

[0005] If a fuel-cut is executed during no-load operation of the diesel engine (i.e., motoring), there is an excess of oxygen in the exhaust gas, causing the oxygen concentration to rise and therefore the filter to become even hotter as re-combustion of the harmful substances is promoted during the regeneration process of the filter, again possibly causing deterioration or breakage. If an exhaust brake is further activated during motoring, the flow rate of the exhaust gas flowing into the filter becomes extremely small, causing the temperature of the filter to rise even more, and again possibly causing deterioration or breakage.

[0006] The present invention solves these problems, and has as an object to provide an exhaust purification device for an internal combustion engine whereby particulate matter in exhaust gas is collected successfully, the exhaust gas is appropriately purified, and breakage due to a rise in temperature of a filter is prevented.

[0007] [Means for Solving the Problems]

An exhaust purification device for an internal combustion engine of the invention of Claim 1 for achieving the above object is provided with a turbo supercharger having a turbine and a compressor, a filter that is provided downstream of the turbine in the exhaust system and collects particulate matter inside exhaust gas, a catalyst

that is provided upstream of the turbine in the exhaust system and has at least oxidizing functionality, a filter regeneration judging means for judging whether or not particulate matter accumulated on the filter have spontaneously ignited or whether or not the filter is undergoing forced regeneration, and an operating state judging means for judging whether or not a specific operating state is in effect whereby a flow rate of exhaust gas flowing into the filter is low, a controlling means supplying a reducing agent to the catalyst when the filter regeneration judging means has judged that particulate matter is undergoing spontaneous ignition or that the filter is undergoing forced regeneration and the operating state judging means has judged that the specific operating state is in effect.

[0008] Accordingly, by supplying reducing agent to the catalyst if the internal combustion engine enters a specific operating state such as a low-rpm/low-load state or idling in which the flow rate of the exhaust gas into the filter is low after particulate matter accumulated on the filter spontaneously ignites or particulate matter is ignited by forced regeneration of the filter, overheating of the filter can be prevented in advance, thereby preventing breakage because any heat produced is carried away by an increased amount of exhaust gas even if sudden combustion of the particulate matter collected on the filter occurs due to a rise in temperature of the exhaust gas at a turbine inlet, or in other words due to a rise in boost pressure because of an increase in exhaust gas energy and

turbine work, which means that an exhaust gas flow rate also increases due to an increased amount of intake air flowing into the internal combustion engine.

[0009] With the exhaust purification device for an internal combustion engine of the invention of Claim 2, the turbo supercharger is constituted by a waste valve that causes the exhaust gas upstream of the turbine in the exhaust system to bypass down to downstream of the turbine or a boost pressure adjusting mechanism whereby boost pressure can be variably controlled, and the controlling means either closes the waste gate valve or controls the boost pressure adjusting mechanism such that the boost pressure rises when the reducing agent is applied to the catalyst. Accordingly, by supplying reducing agent to the catalyst after [the internal combustion engine] enters the specific operating state after the particulate matter accumulated on the filter has ignited, the temperature of the exhaust gas at the turbine inlet rises and either the waste gate valve is closed or the boost pressure is caused to rise, thereby effectively increasing turbine work and raising the boost pressure because the hot exhaust gas is no longer bypassed down to downstream of the turbine via the waste gate valve or the boost pressure adjusting mechanism. In other words, the amount of air taken into the internal combustion engine increases, thereby causing the exhaust gas flow rate to increase, and even if sudden combustion of the particulate matter accumulated on the filter occurs, the produced heat is carried away by the exhaust

gas, making it possible to prevent overheating of the filter in advance.

[0010] With the exhaust purification device of the invention of Claim 3, the controlling means supplies reducing agent to the catalyst when the filter regeneration judging means judges that particulate matter is spontaneously igniting or the filter is undergoing forced regeneration, and the operating state judging means judges that the specific operating state has continued for at least a predetermined amount of time. Accordingly, by supplying reducing agent to the catalyst only when the specific operating state of the internal combustion engine has continued for at least a predetermined amount of time, overheating of the filter can be prevented ahead of time by increasing the flow rate of the exhaust gas, but, on the other hand, wasteful supply of reducing agent can also be prevented since there is no need to increase the flow rate of the exhaust gas when [the length of time of] the specific operating state of the internal combustion engine a short, because the filter does not undergo overheating.

[0011] With the exhaust purification device for an internal combustion engine of the invention of Claim 4, an accumulated amount estimating means for estimating an accumulated amount of particulate matter collected on the filter is provided, the turbo supercharger is constituted by a waste valve that causes the exhaust gas upstream of the turbine in the exhaust system to bypass down to downstream of the

turbine or a boost pressure adjusting mechanism, and the controlling means supplies reducing agent to the catalyst and either opens the waste gate valve or controls the boost pressure adjusting mechanism such that the boost pressure falls when an accumulated amount of particulate matter estimated by the accumulated amount estimating means exceeds a predetermined value. Accordingly, by supplying reducing agent to the catalyst when it is judged that an accumulated amount of particulate matter on the filter has exceeded a predetermined amount and forced regeneration of the filter is required, the temperature of the exhaust gas at the turbine inlet rises and either the waste gate valve is opened or the boost pressure is lowered, thereby making it possible to regenerate the filter by effectively raising the temperature of the exhaust gas and combusting the particulate matter, without increasing the turbine work, because the hot exhaust gas is bypassed down to downstream of the turbine via the waste gate valve or the boost pressure adjusting mechanism.

[0012] With the exhaust purification device for an internal combustion engine of the invention of Claim 5, the specific operating state is an operating state in which an exhaust gas flow rate falls to within a specific range due to activation of an exhaust brake during ordinary operation or during motoring with fuel supply stopped, and the controlling means supplies reducing agent to the catalyst if in the specific operating state the filter regeneration judging means judges that particulate matter is spontaneously

igniting or the filter is undergoing forced regeneration. Accordingly, by supplying reducing agent the catalyst after the internal combustion engine enters an operating state in which the exhaust gas flow rate falls to within a specific range due to activation of an exhaust brake during ordinary operation or during motoring with fuel supply stopped after the particulate matter accumulated on the filter spontaneously ignites or the particulate matter ignites due to forced regeneration of the filter, the exhaust gas at the turbine inlet is heated, the turbine work is increased, and the boost pressure is increased. In other words, the flow rate of exhaust gas is increased by increasing the amount of intake air to the internal combustion engine, and even if sudden combustion of the particulate matter accumulated on the filter occurs, the generated heat is carried away by the increased exhaust gas. Furthermore, the break characteristics of the exhaust brake can be maintained while preventing overheating of the filter in advance.

[0013] Note that in the inventions of claims described above, the specific means whereby the controlling means supplies reducing agent to the catalyst may be post-injection whereby additional fuel is injected during either an expansion process or an exhaust process after main fuel injection, or additional injection whereby fuel is injected separately from the main fuel injection into the exhaust system upstream of the catalyst, or may control injection timing or fuel amount, for example, such that a combustion state of the main

fuel is a partially ignited state.

[0014] [Embodiments of the Invention]

Embodiments of the present invention are described in detail below with reference to the drawings.

[0015] Figure 1 shows a schematic constitution of an exhaust purification device for an internal combustion engine according to one embodiment of the present invention, Figure 2 shows a flowchart of control of execution of forced regeneration of the filter according to the exhaust purification device for an internal combustion engine of the present embodiment, Figure 3 shows a flowchart of control of forced regeneration of the filter according to the exhaust purification device for an internal combustion engine of the present embodiment, Figure 4 shows a flowchart of control for preventing breakage during forced regeneration of the filter according to the exhaust purification device of an internal combustion engine of the present embodiment, and Figure 5 shows a graph for explaining a specific operating state in a diesel engine.

[0016] As shown in Figure 1, in the exhaust purification device for an internal combustion engine according to the present embodiment, a diesel engine 11, acting as the internal combustion engine, is such that an intake pipe 13 is connected to an intake port facing a combustion chamber which is not shown in the drawings via an intake manifold 12, an air cleaner 14 is attached to an air inlet hole of the intake pipe 13, and an inter cooler 15 is attached along

[the intake pipe 13]. An exhaust pipe 17 is connected to an exhaust port not shown in the drawings of the engine 11 by an exhaust manifold 16.

[0017] A turbo supercharger 18 is provided to the engine 11. The turbo supercharger 18 is constituted by linking along a single axis a compressor 19 that is provided to the intake pipe 19 and a turbine 20 that is provided to the exhaust pipe 17. On the exhaust pipe 17, a diesel particulate filter (DPF, hereafter referred to simply as a filter) 21 that collects particulate matter (PM: harmful substances such as black smoke) is provided downstream of the turbine 20 of the turbo supercharger 18, while an oxidation catalyst 22 is provided upstream of the turbine 20. Furthermore, a bypass passage 23 is connected to the exhaust pipe 17 so as to bypass the turbine 20 of the turbo supercharger 18, and a waste gate valve 24 is provided to the bypass passage 23.

[0018] Furthermore, exhaust temperature sensors 25, 26 and exhaust pressure sensors 27, 28 are provided upstream and downstream of the filter 21. An engine rpm sensor 29 that detects engine rpm is provided to the engine 11.

[0019] Moreover, a vehicle is provided with an ECU (electronic control unit) 30 having an I/O device, a storage device (ROM, RAM, non-volatile RAM, etc.), a central processing unit (CPU), a timer counter, and so on, overall control including the engine 11 being performed by the ECU 30. Specifically, the exhaust temperature

sensors 25, 26, the exhaust pressure sensors 27, 28, and the engine rpm sensor 29, along with an accelerator aperture sensor 31, an exhaust brake switch 32, and so on are connected to an input side of the ECU 30, detection data from these sensors being input thereinto. A driver 33 of an injector that is not shown in the drawings and so on are connected to an output side of the ECU 30, optimal values of fuel injection amounts, ignition timing, and the like calculated on the basis of the detection data from the various sensors being output to the driver 33 of the injector and so on. Furthermore, the waste gate valve 24 that opens and closes the bypass passage 23 is connected to the output side of the ECU 30, and is opened and closed according to the operating state of the engine.

[0020] With the exhaust purification device for an internal combustion engine according to the present embodiment, exhaust gas flows out of the engine 11 through the exhaust pipe 17 and into the oxidation catalyst 22 and the filter 21. With the oxidation catalyst 22, CO and HC in the exhaust gas is purified, and in the filter 21, particulate matter in the exhaust gas is collected. The particulate matter collected by the filter 21 is re-combusted either through spontaneous ignition or through forced regeneration of the filter 21, thereby regenerating the filter 21. In this case, when the engine 11 is operated in a high-rpm/high-load state, the temperature of the exhaust gas reaches the ignition temperature of the particulate matter (e.g., 600 °C) and the particulate matter naturally ignites

and thereby combusts. On the other hand, for forced regeneration of the filter 21, when the amount of particulate matter accumulated on the filter 21 reaches or exceeds a predetermined amount, CO and HC from the fuel are combusted by the oxidation catalyst 22 using post-injection whereby additional fuel is injected during the expansion step or the exhaust step after main fuel injection, causing the exhaust gas to rise in temperature and heat the filter 21, thereby causing the accumulated particulate matter to forcibly ignite and combust.

[0021] In regeneration control of the filter 21, the ECU (controlling means) 30 judges (filter regeneration judging means) whether or not the particulate matter accumulated on the filter 21 is undergoing spontaneous ignition or whether or not the filter 21 is undergoing forced regeneration, judges (operating state judging means) whether or not a specific operating state is in effect whereby a flow rate of exhaust gas flowing into the filter 21 is low, and supplies to the oxidation catalyst 22 a reducing agent, or in other words CO and HC through post-injection, when the particulate matter is undergoing spontaneous ignition or the filter 21 is undergoing forced regeneration and a specific operating state is in effect.

[0022] Specifically, the specific operating state whereby the flow rate of exhaust gas flowing into the filter 21 is low is, for example, the area A shown in Figure 5, such as low-rpm/low-load operation or idling of the engine 11 in which an engine rpm Ne is low

and a fuel injection amount Q is low. In this specific operating state, the amount of new air flowing in decreases due to the drop in rpm, and the flow rate of the exhaust gas becomes extremely small and the oxygen concentration rises because the fuel supply amount drops. If a regeneration process of the filter 21 is performed at this time, the particulate matter accumulated on the filter 21 more readily combusts, and heat produced by combustion of the particulate matter cannot be carried away, leading potentially to deterioration or breakage of the filter 21 due to a temperature rise therein.

[0023] Accordingly, if the engine 11 enters the specific operating state whereby the flow rate of the exhaust gas flowing into the filter 21 drops after a regeneration process is executed by igniting the particulate matter accumulated on the filter 21, then supplying CO and HC to the oxidation catalyst 22 through post-injection causes the exhaust gas at an entry hole of the turbine 21 to rise in temperature, thereby increasing the energy of the exhaust gas, increasing turbine work, and raising the boost pressure of the turbo supercharger 18. When this happens, the amount of air taken into the engine 11 increases, and the exhaust gas flow rate flowing into the filter 21 also increases as a result. Even if sudden ignition of the particulate matter accumulated on the filter 21 occurs, the heat thus produced is carried away by the increased exhaust gas, thereby making it possible to prevent overheating of the filter 21 in advance.

[0024] A detailed description is given of forced regeneration control and breakage prevention control of the filter 21 described above in the exhaust purification device of the present embodiment.

[0025] As shown in Figure 2, in forced regeneration execution control, the ECU 30 reads output signals from the various sensors in step S1, and in step S2 performs a judgment as to whether or not a predetermined amount or more of particulate matter has accumulated on the filter 21. In this case, an accumulated amount of particulate matter on the filter 21 is estimated based on pressure loss in the filter 21. Specifically, pressure loss in the filter 21 with respect to flow rate of the exhaust gas and an accumulated amount of particulate matter with respect to the pressure loss are calculated in advance, and several maps are set for pressure loss-accumulated amount of particulate matter corresponding to the flow rate of the exhaust gas. On the other hand, pressure loss based on exhaust pressures upstream and downstream of the filter 21 as detected by the exhaust pressure sensors 27, 28 is calculated, and an accumulated amount of particulate matter is estimated based on this pressure loss from the several maps set in advance.

[0026] Note that the accumulated amount of particulate matter of the filter 21 can be estimated not solely using a method based on the detection results of the exhaust pressure sensors 27, 28, but may also be estimated using a pressure differential sensor capable of detecting a pressure difference between an upstream side and a

downstream side of the filter 21, or on the basis of cumulative low-rpm/low-load operation time for the engine during which spontaneous ignition of the particulate matter having been left [sic: synonym for "accumulated"] on the filter 21 does not readily occur, or on the basis of the number of spontaneous ignitions during which the particulate matter is combusted which has accumulated on the filter 21 and the cumulative engine operation time.

[0027] In step S2, a judgment is made as to whether or not the estimated accumulated amount of the particulate matter on the filter 21 is greater than or equal to a predetermined amount, or in other words is greater than or equal to an accumulated amount of particulate matter at which pressure loss in the filter 21 is large enough to adversely affect combustion efficiency, and if the accumulated amount of particulate matter is greater than or equal to a predetermined amount, then [the ECU 30] enters a forced regeneration mode in step S3.

[0028] When the forced regeneration mode is entered, the ECU performs forced regeneration control as shown in Figure 3. In step S11, the ECU 30 reads output signals from the various sensors, and in step S12, makes a judgment as to whether or not the particulate matter accumulated on the filter 21 is ignited. Ignition of the particulate matter on the filter 21 occurs when the exhaust gas temperature is greater than or equal to an ignition temperature (e.g., 600 °C), and the particulate matter ignition judgment is made

by comparing an average value T_a of exhaust temperatures T_1 and T_2 upstream and downstream of the filter 21 as detected by the exhaust temperature sensors 25, 26 (i.e., $T_a = (T_1 + T_2) / 2$) with a particulate matter ignition temperature T_0. Specifically, in step S12 if the average exhaust temperature T_a is not greater than or equal to the particulate matter ignition temperature T_0, the particulate matter on the filter 21 is judged not to be ignited, and post-injection is performed in step S13 and in step S14 the waste gate valve 24 is operated and the bypass passage 23 is opened.

[0029] Accordingly, CO and HC are supplied as a reducing agent to the oxidation catalyst 22 via the exhaust pipe 17 through post-injection, and the exhaust gas rises in temperature due to the CO and HC being combusted through catalytic action in the oxidation catalyst 22. The exhaust gas at the entry hole of the turbine 20 becomes hot and is supplied to the filter 21 through the bypass passage 23 of the turbo supercharger 18, thereby heating the filter 21, and the particulate matter accumulated on the filter 21 is forcibly ignited and combusted.

[0030] In step S16, a judgment is made as to whether or not or civil regeneration of the filter 21 is complete. This judgment may be made similarly to the judgment of the accumulated accumulated [sic] amount the particulate matter step S2 in the forced regeneration execution control described above based on a pressure difference in the exhaust pressure upstream and downstream of the filter 21 as

detected by the exhaust pressure sensors 27 and 28, or may be made using a different method. In step S16, if forced regeneration of the filter 21 is not complete, the process returns to step S11, and steps S11-S16 are repeated. If particulate matter is continuously ignited throughout this process, the process moves from step S12 to step S15, and post-injection is stopped.

[0031] Note that in order to cause the particulate matter accumulated on the filter 21 to ignite, post-injection was performed whereby additional fuel is injected during the expansion step or the exhaust step after the main fuel injection, but if it is possible to supply the reducing agent such as HC or CO to the oxidation catalyst 22, post-injection is not necessary. For example, additional injection is also possible whereby additional fuel is injected separate from the main fuel injection into the exhaust system upstream of the oxidation catalyst 22, or it is also possible to control injection timing and/or fuel amount such that the combustion state of the main combustion is partially ignition.

[0032] Thereafter, if the forced regeneration process of the filter 21 is judged in step S16 to have been completed, the process moves to step S17 and the forced opening of the waste gate valve 24 is stopped and ordinary control is returned to.

[0033] At the same time, during execution of the forced regeneration control in this forced regeneration mode, breakage prevention control is also executed for the filter 21. As shown in

Figure 4, in breakage prevention control, the ECU 30 reads output signals from the various sensors in step S21, and in step S22 makes a judgment as to whether or not the filter 21 is undergoing forced regeneration (forced regeneration mode). In this case, a forced regeneration mode graph is set when entering forced regeneration mode in step S3 of forced regeneration execution control, and once forced regeneration of the filter 21 is complete in step S16 of forced regeneration control, control is performed so as to reset the forced regeneration mode graph, and the judgment in step S22 is made as to whether or not the forced regeneration mode graph has been set. In step S22, if the filter is judged to be undergoing forced regeneration, then the process moves to step S25 and a judgment is made as to whether or not the engine 11 is in the specific operating state.

[0034] On the other hand, if in step S22 the filter 21 is judged not to be undergoing forced regeneration, then in step S23 a judgment is made as to whether or not the accumulated amount of particulate matter is equal to or greater than a predetermined value, and if the accumulated amount of particulate matter is greater than or equal to the predetermined amount, then the process moves to step S24, but if the accumulated amount of particulate matter is not greater than or equal to a predetermined amount, nothing is done and this routine is exited. In step S24, a judgment is made as to whether or not the particulate matter accumulated on the filter 21 is undergoing natural

ignition, and if the particulate matter is ignited, a judgment is made as to whether or not the engine 11 is in the specific operating state, but if the particulate matter is not ignited, nothing is done and this routine is exited.

[0035] The specific operating state judge in step S25 is, as described above, a state whereby the flow rate of exhaust gas flowing into the filter 21 is low, such as for example low-rpm/low-load operation or idling of the engine 11 in which the engine rpm Ne is low and the fuel injection amount Q is low (the area A shown in Figure 5). The ECU 30 judges the area based on the map in Figure 5, using the engine rpm Ne detected by the engine rpm sensor 29 and the fuel injection amount Q calculated from the accelerator aperture detected by the accelerator aperture sensor 31, thereby making a judgment as to whether or not the specific operating state is in effect.

[0036] If the judgment in step S25 is that the specific operating state is in effect, then the continuous time thereof is added up in step S26, and in step S27 a judgment is made as to whether or not the continuous time of the specific operating state is greater than or equal to a predetermined amount of time. Specifically, if the engine 11 enters, for example, a low-rpm/low-load operating state during forced regeneration during which the particulate matter on the filter 21 is combusting or when the accumulated amount of particulate matter is greater than or equal to

a predetermined value and the particulate matter is undergoing spontaneous ignition, then the exhaust gas flow rate becomes extremely small with the filter 21 remaining at a high temperature, and the heat produced by combustion of the particulate matter cannot be carried away by the exhaust gas, leading to an extremely high temperature of and potentially breakage of the filter 21. A predetermined amount of time judged in step S27 is a time limit in order to prevent breakage of the filter 21 due to high temperature, and if the continuous time of the specific operating state is not greater than or equal to the predetermined amount of time, nothing is done and this routine is exited.

[0037] If the continuous time of the specific operating state is greater than or equal to the predetermined amount of time in step S27, post-injection is performed in step S28, and in step S29 the waste gate valve 24 is activated in the bypass passage 23 is closed. Accordingly, CO and HC are supplied as a reducing agent to the oxidation catalyst 22 via the exhaust pipe 17 through post-injection, and the exhaust gas rises in temperature due to the CO and HC being combusted through catalytic action in the oxidation catalyst 22. The exhaust gas at the entry hole of the turbine 20 reaches a high temperature, expands in volume, and enters the turbine 20 of the turbo supercharger 18 without passing through the bypass passage 23. Because the energy of the exhaust gas which has flowed in increases in the turbo supercharger 18, the work of the turbine 20 increases,

raising the boost pressure, or in other words the work of the compressor 19 also increases, increasing the amount of intake air and also increasing the flow rate of the exhaust gas. As a result, even if the particulate matter accumulated on the filter 21 suddenly combusts, the heat generated thereby is carried away by the increased amount of exhaust gas, thereby limiting overheating of the filter 21 and making it possible to prevent breakage thereof.

[0038] Note that in the above embodiment the specific operating state judge was a state whereby the flow rate of exhaust gas flowing into the filter 21 is low, such as for example low-rpm/low-load operation or idling of the engine 11 in which the engine rpm Ne is low and the fuel injection amount Q is low (the area A shown in Figure 5), but the present invention is not limited to this area. For example, during medium-to-high-rpm/no-load operation of the engine 11, the flow rate of the exhaust gas increases when a fuel-cut is executed (motoring), and if the exhaust brake 32 is activated during motoring, and the vowel in the exhaust pipe 17 is closed, stopping the flow of the exhaust gas. Therefore, the flow rate of the exhaust gas flowing into the filter 21 becomes extremely small in this specific operating state, which is shown in area B in Figure 5.

[0039] By activating the exhaust brake 32 during motoring when the particulate matter on the filter 21 is undergoing spontaneous ignition or when the filter 21 is undergoing forced regeneration, if the specific operating state in which the exhaust gas flow rate

becomes extremely small is entered into and continued for a predetermined amount of time, post-injection is performed, the waste gate valve 24 is activated, and the bypass passage 23 is closed. Accordingly, CO and HC are supplied to the oxidation catalyst 22 through the exhaust pipe 17 by the post-injection, the CO and HC are combusted by the catalytic action of the oxidation catalyst 22, the exhaust gas rises in temperature, the exhaust gas energy at the entry hole for the turbine 20 rises, and the work of the turbine 20 increases, thereby increasing the amount of intake air and the exhaust gas flow rate.

[0040] Note that even in a state in which the exhaust brake 32 is not activated during motoring, it is also possible to perform post-injection to lower the oxygen concentration in specific operation whereby the flow rate of the exhaust gas falls because of the decreased engine rpm.

[0041] Even if the filter 21 is undergoing forced regeneration and motoring is being performed, when the temperature of the filter 21 is low (i.e., the average exhaust temperature T_a), performing post-injection, activating the waste gate valve 24, and opening the bypass passage 23 results in high-temperature exhaust gas passing through the bypass passage 23 and being supplied to the filter 21 which it heats, thereby making it possible to prevent over-cooling [sic] of the filter 21.

[0042] Note that in the above embodiment, turbo supercharger 18

is constituted by linking on a single axis the compressor 19 and the turbine 20, and the waste gate valve 24 is provided to the exhaust pipe 17 by connecting the bypass passage 23, but it is also possible to use a variable capacity-type supercharger for the turbo supercharger in which the most pressure can be adjusted. A variable capacity-type supercharger is constituted by rotatably arranging nozzle vanes around the turbine and linking the nozzle vanes by a ring, and the charging pressure can be adjusted by changing the angle of the nozzle vanes with the ring using an actuator.

[0043] With the exhaust purification device using this variable capacity-type supercharger, the boost pressure is controlled by the forced regeneration control of the filter 21 so as to decrease using the post-injection and the variable capacity-type supercharger, the CO and HC thereby being supplied to the oxidation catalyst 22 as a reducing agent by the post-injection. In the oxidation catalyst 22, the CO and HC are combusted by the catalytic action, the exhaust gas rises in temperature, and the boost pressure falls, thereby facilitating the supply of high-temperature exhaust gas to the filter 21 and heating [the filter 21]. Therefore, the particulate matter accumulated on the filter 21 is combusted by the forced ignition, making it possible to regenerate the filter 21.

[0044] If, in breakage prevention control of the filter 21, the specific operating state whereby the exhaust gas flow rate is extremely small, continues for a predetermined amount of time, CO and

HC are supplied to the oxidation filter 22 as a reducing agent after forming post-injection and controlling the boost pressure with the variable capacity-type supercharger so as to rise. The CO and HC thereby combust in the oxidation catalyst 22 due to the catalytic action, the exhaust gas rises in temperature and the boost pressure rises. The exhaust gas energy at the entry hole for the turbine 20 therefore increases, the work of the turbine 20 increases, and thereby the amount of air flowing in increases and the flow rate of the exhaust gas rises. As a result, even if the particulate matter accumulated on the filter 21 suddenly combusts, the heat generated thereby is carried away by the increased amount of exhaust gas, thereby limiting overheating of the filter 21 and making it possible to prevent breakage thereof.

[0045] [Effects of the Invention]

As described in detail in the embodiments above, the exhaust purification device for an internal combustion engine of the invention of Claim 1 is provided with a turbo supercharger having a turbine and a compressor, a filter that is provided downstream of the turbine in the exhaust system and collects particulate matter inside exhaust gas, a catalyst that is provided upstream of the turbine in the exhaust system and has at least oxidizing functionality, a filter regeneration judging means for judging whether or not particulate matter accumulated on the filter has spontaneously ignited or whether or not the filter is undergoing forced regeneration, and an operating

state judging means for judging whether or not a specific operating state is in effect whereby a flow rate of exhaust gas flowing into the filter is low, a controlling means supplying a reducing agent to the catalyst when the filter regeneration judging means has judged that particulate matter is undergoing spontaneous ignition or that the filter is undergoing forced regeneration and the operating state judging means has judged that the specific operating state is in effect, and therefore the temperature of the exhaust gas at the turbine entry rises, the energy of the exhaust gas increases, the turbine work increases, and the boost pressure rises, or in other words the exhaust gas flow rate also increases because the amount of air taken into the internal combustion engine rises, and even if sudden ignition of the particulate matter collected on the filter occurs, the heat thus produced is carried away by the increased exhaust gas, thereby making it possible to limit overheating of the filter and prevent breakage thereof.

[0046] With the exhaust purification device for an internal combustion engine of the invention of Claim 2, the turbo supercharger is constituted by a waste valve that causes the exhaust gas upstream of the turbine in the exhaust system to bypass down to downstream of the turbine or a boost pressure adjusting mechanism whereby boost pressure can be variably controlled, and the controlling means either closes the waste gate valve or controls the boost pressure adjusting mechanism such that the boost pressure rises when the reducing agent

is applied to the catalyst, and therefore by supplying reducing agent to the catalyst after [the internal combustion engine] enters the specific operating state after the particulate matter accumulated on the filter has ignited, the temperature of the exhaust gas at the turbine inlet rises and either the waste gate valve is closed or the boost pressure is caused to rise, thereby effectively increasing turbine work and raising the boost pressure because the hot exhaust gas is no longer bypassed down to downstream of the turbine via the waste gate valve or the boost pressure adjusting mechanism. In other words, the amount of air taken into the internal combustion engine increases, thereby causing the exhaust gas flow rate to increase, and even if sudden combustion of the particulate matter accumulated on the filter occurs, the produced heat is carried away by the exhaust gas, making it possible to prevent overheating of the filter in advance.

[0047] With the exhaust purification device of the invention of Claim 3, the controlling means supplies reducing agent to the catalyst when the filter regeneration judging means judges that particulate matter is spontaneously igniting or the filter is undergoing forced regeneration, and the operating state judging means judges that the specific operating state has continued for at least a predetermined amount of time, and therefore by supplying reducing agent to the catalyst only when the specific operating state of the internal combustion engine has continued for at least a predetermined

amount of time, overheating of the filter can be prevented ahead of time by increasing the flow rate of the exhaust gas, but, on the other hand, wasteful supply of reducing agent can also be prevented since there is no need to increase the flow rate of the exhaust gas when [the length of time of] the specific operating state of the internal combustion engine a short, because the filter does not undergo overheating.

[0048] With the exhaust purification device for an internal combustion engine of the invention of Claim 4, an accumulated amount estimating means for estimating an accumulated amount of particulate matter collected on the filter is provided, the turbo supercharger is constituted by a waste valve that causes the exhaust gas upstream of the turbine in the exhaust system to bypass down to downstream of the turbine or a boost pressure adjusting mechanism, and the controlling means supplies reducing agent to the catalyst and either opens the waste gate valve or controls the boost pressure adjusting mechanism such that the boost pressure falls when an accumulated amount of particulate matter estimated by the accumulated amount estimating means exceeds a predetermined value, and therefore by supplying reducing agent to the catalyst when it is judged that an accumulated amount of particulate matter on the filter has exceeded a predetermined amount and forced regeneration of the filter is required, the temperature of the exhaust gas at the turbine inlet rises and either the waste gate valve is opened or the boost pressure

is lowered, thereby making it possible to regenerate the filter by effectively raising the temperature of the exhaust gas and combusting the particulate matter, without increasing the turbine work, because the hot exhaust gas is bypassed down to downstream of the turbine via the waste gate valve or the boost pressure adjusting mechanism.

[0049] With the exhaust purification device for an internal combustion engine of the invention of Claim 5, the specific operating state is an operating state in which an exhaust gas flow rate falls to within a specific range due to activation of an exhaust brake during ordinary operation or during motoring with fuel supply stopped, and the controlling means supplies reducing agent to the catalyst if in the specific operating state the filter regeneration judging means judges that particulate matter is spontaneously igniting or the filter is undergoing forced regeneration. Accordingly, by supplying reducing agent the catalyst after the internal combustion engine enters an operating state in which the exhaust gas flow rate falls to within a specific range due to activation of an exhaust brake during ordinary operation or during motoring with fuel supply stopped after the particulate matter accumulated on the filter spontaneously ignites or the particulate matter ignites due to forced regeneration of the filter, the exhaust gas at the turbine inlet is heated, the turbine work is increased, and the boost pressure is increased. In other words, the amount of air taken into the internal combustion engine increases, thereby

causing the exhaust gas flow rate to increase, and even if sudden combustion of the particulate matter accumulated on the filter occurs, the produced heat is carried away by the exhaust gas, making it possible to prevent overheating of the filter in advance while maintaining brake characteristics of the exhaust brake.

[Brief Description of the Drawings]

[Figure 1] shows a schematic constitution of an exhaust purification device for an internal combustion engine according to one embodiment of the present invention.

[Figure 2] shows a flowchart of control of execution of forced regeneration of the filter according to the exhaust purification device for an internal combustion engine of the present embodiment.

[Figure 3] shows a flowchart of control of forced regeneration of the filter according to the exhaust purification device for an internal combustion engine of the present embodiment.

[Figure 4] shows a flowchart of control for preventing breakage during forced regeneration of the filter according to the exhaust purification device of an internal combustion engine of the present embodiment.

[Figure 5] shows a graph for explaining a specific operating state in a diesel engine.

[Explanation of Reference Numbers]

11 diesel engine (internal combustion engine)

17 exhaust pipe

18 turbo supercharger

19 compressor

20 turbine

21 diesel particulate filter (DPF, filter)

22 oxidation catalyst (catalyst)

23 bypass passage

24 waste gate valve

25, 26 exhaust temperature sensors

27, 28 exhaust pressure sensors

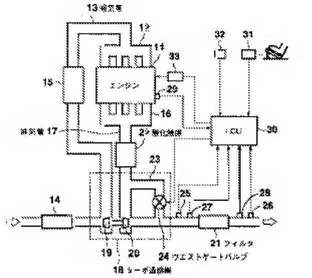
29 engine RPM sensor

30 ECU, electronic control unit (filter regeneration judging means, operating state judging means, controlling means)

31 accelerator aperture sensor

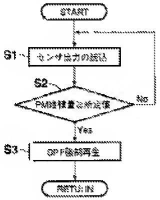
32 exhaust brake switch

FIG. 1



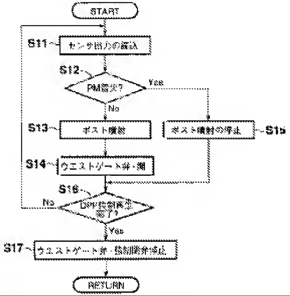
13- intake pipe
17- exhaust pipe
22- oxidation catalyst
18- turbo supercharger
24- waste gate valve
21- filter

FIG. 2



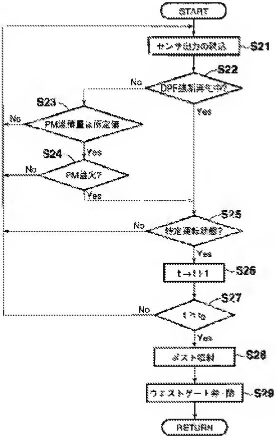
S1- Read sensor output
S2- Particulate matter accumulated amount ≥ predetermined value?
S3- DPF forced regeneration

FIG. 3 /9



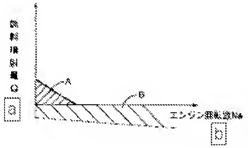
S11- Read sensor output
S12- Particulate matter ignited?
S13- Post-injection
S14- Open waste gate valve
S15- Stop post-injection
S16- DPF forced regeneration complete?
S17- Stop waste gate valve/forced valve closure

FIG. 4



S21- Read sensor output
S22- Is DPF under forced regeneration?
S23- Particulate matter accumulated amount ≥ predetermined value?
S24- Particulate matter ignited?
S25- Specific operating state?
S26- t → t+1
S27- $t \geq t_0$
S28- Post-injection
S29- Open waste gate valve

FIG. 5



Key:
a) Fuel injection amount Q
b) Engine rpm Ne